TAP 515-3: Modelling radioactive decay

Use dice, coins or a computer model to simulate the random decay of radioactive nuclei. Plot a graph showing how the number of remaining 'nuclei' changes with time.

The chance throw of dice illustrates radioactive decay very clearly. You need a large number (over 100) dice for this activity to work. If you don't have enough dice, then you will be able to imagine the sort of results you might get, so keep reading.

Let's suppose that an atom of an isotope has a 1 in 6 chance of decaying in any one minute. We can simulate this by throwing a die representing the atom; if a six comes up, we can say that the atom has decayed.

Now with 100 or more dice we have a model of a (very small) sample of radioactive isotope. Each time we shake the dice assume that another minute of the sample's life has passed. In this time more 'nuclei' have decayed – the ones that came up six.

Shake the dice.

Count and remove the sixes.

Repeat the procedure, completing a table like table below, until all the dice have 'decayed'.

Time/min	No. of 'active' nuclei, N (i.e. no. of dice thrown)	No. of decays (i.e. no. of sixes)

If you have time, repeat the whole process.

Plot a graph showing how the number of surviving dice changes with time.

Plot a graph of log (N) against t and hence decide whether the decay really is exponential.

You could also plot graphs to show how 'activity', i.e. the number of decays per minute, varies with time. Use suitable tests to decide whether activity changes exponentially.

Practical advice

In previous episodes, students may have met examples of exponential change that are all determined by equations that describe the particular situation exactly. Radioactive decay, on the other hand, involves a degree of randomness – this is clear from simple observations such as the production of tracks in a cloud chamber, or listening to 'clicks' from a GM counter. The aim of this activity is to demonstrate that a decay process that is governed by independent probabilities can (indeed must) be exponential – an important point, which should not be glossed over.

There are a number of simulations of radioactive decay in physics software packages and any of them could be used at this stage. However, students readily understand the laws of probability that govern the throw of dice, so the one outlined on in TAP 515-3 remains an excellent demonstration. The 'experiment' should take only a few minutes, plus graph-plotting time.

Another good analogy for radioactive decay is liquid draining from a cylindrical container through a capillary tube. The flow-rate is proportional to the pressure due to the liquid, which is proportional to its depth. The rate at which the depth of liquid decreases is thus proportional to the depth itself. A graph of depth against time will be an exponential decay curve, and a log-linear graph will be a straight line. Obtain data by marking the position of the water surface at regular intervals as the water slowly drains from the cylinder.

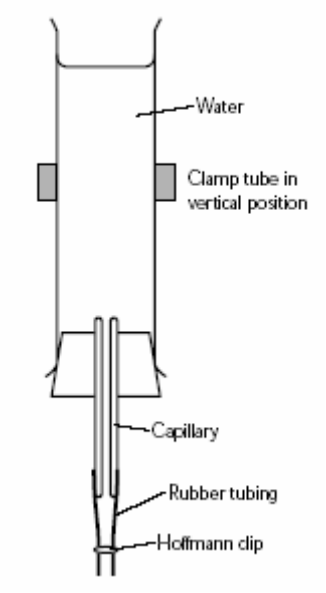
Technicians' notes

Apparatus dice model

- ✓ Dice (identical if possible) *or* small wooden cubes (approx 1 cm^3) with one face coloured
- ✓ At least 100 dice or cubes are needed.

Water- flow model

- ✓ wide glass tube (4–5 cm diameter), pierced bung to fit tube capillary tube to fit bung, rubber tube to fit capillary
- ✓ Hoffmann clip
- ✓ clamp, boss and stand
- ✓ marker pen
- ✓ stopwatch
- ✓ container to catch water draining from tube
- ✓ Assemble the apparatus as shown in below, and arrange for the outlet to be over a large container, or sink if conveniently located. Ensure the Hoffmann clip is closed, and fill the wide tube with water.



Above: Modelling radioactive decay using water flow

Alternatively, a computer running a simulation of radioactive decay may be requested.

External reference

This activity is taken from Salters Horners Advanced physics, A2, STA activity 10.